of the satellite's shadows as they were projected on the extreme points of the two axes of the spot, the mean giving the position of the spot's centre. In the case of the third satellite, when its latitude was – 1° 45′ 14″, that of its shadow—reckoning from the bottom side of the spot—was – 30° 34′ 36″. The latitude of the shadow of the second satellite came out to be – 17° 48′ 10″, and after allowing for the fact that it was projected tangentially on the side of the spot and for the diffraction of the instrument, this value for the latitude of the north side of the spot became – 20° 56′ 37″. Taking the mean of the values obtained from both satellites, the latitude of the centre was – 25° 45′ 36″, and, with the polar semi-diameter as unity, the magnitude of the spot was 0·20297.

The mean value of the latitude obtained from eleven observations by Denning, Green, Ricco, Williams, Keeler, and Terby was 21°·5 ± 2°·05, the major and minor axes of the spot being 0·555 and 0·188 respectively. Using the micrometer, the latitude, according to Young, amounted to 40°; while Denning estimated that the major axis embraced an arc varying between 29°·3 and 37°·8.

A Mean Time Sun-dial.—A very ingenious sun-dial, capable of indicating mean time, has been recently invented by Major-General Oliver, the construction of the instrument being undertaken by Messrs. Negretti and Zambra. In an ordinary sun-dial, the time is read off generally by the position of the centre of a shadow, cast by a straight-edged style, on a flat surface on which the hours are graduated. The peculiarity of the present instrument is that the time is indicated by the position of the *edge* of a shadow cast by a "nine-pin" shaped style, with regard to an equatorial circular line. The style is fixed along the diameter of a semicircular arc, which is clamped by means of a screw to a firm stand to suit any latitude; at right angles to this arc, and also capable of adjustment, is another semicircle, graduated in five-minute divisions. Owing to the change of declination of the sun throughout the year, different *parts* of the shadow of the style are brought on to the hour circle in such a way that the difference between the time indicated (by the dial) and mean time, or the equation of time, is counterbalanced by the change in position of the shadow, due to the peculiar form of the style. If we start, for instance, on December 24, the readings have to be taken from the shadow of the eastern edge of the lower part of the style in an upward direction, the bulging out of the style counteracting the increase and decrease of the equation of time (which is here positive) until June 14 is reached. Owing to the thickness of the style's axis, a slight adjustment is here necessary when we pass to the other side of the style; this adjustment is facilitated by placing the twelve o'clock graduation to the western of two marks shown on the vertical circle. This being done, the readings from the shadow, cast now by the western side of the upper protuberance, are taken until the other nodal point on June 14 is reached. At this time also—in fact, four times a year—this slight alteration has to be made. From this latter date until December 24 is reached the same process is repeated, only the respective opposite sides of the style are used in the inverse order. To obviate the necessity of having two styles, which, of course, would have to be the case if the greatest accuracy were desired, owing to the differences in the maximum values of the equation of time, one with a mean contour is given: the error produced by this is practically very slight, amounting in time to about one-sixteenth of greatest value of the equation of time—a quantity scarcely appreciable, on account of the lack of sharpness of the edge of the shadow.

Comet Swift (1892 March 6).—*Edinburgh Circular* No. 28 contains a continuation of the ephemeris of Comet Swift (March 6, 1892) for the month of July and part of August, from which we make the following extract:—

Berlin Midnight.

1892.	R.A.	Decl.	log Δ.	log *r*.	Br
	h. m. s.	° ′			
July 7	0 52 36	+48 0·5			
8	53 33	12·6	0·2391	0·2552	0·17
9	54 28	24·5			
10	55 20	36·2			
11	56 10	47·7			
12	56 58	59·0	0·2427	0·2665	0·16
13	57 43	49 10·0			

The brightness at the time of discovery being taken as the unit of brightness, it will be seen that the comet is at present more than five times dimmer than it was in March. In fact, it is rapidly becoming invisible, and will only be able to be observed with large instruments for another two months or so. Its position on July 7 will lie to the very southern extremity of the constellation of Cassiopeia, forming nearly an equilateral triangle with ξ and π.

Stars' Proper Motions.—Mr. J. G. Porter contributes to the *Astronomical Journal*, No. 268, a catalogue of the proper motions of 301 stars, which amount to half a second or more in a year. This list, as he informs us, is from a still more extensive catalogue which he hopes soon to publish; and the proper motions contained in it are rendered more trustworthy by the enlightenment of new observations. The positions of the stars are all brought up to the epoch 1900·0.

GEOGRAPHICAL NOTES.

M. Charles Alluaud describes his researches on the Island of Mahé, the largest of the Seychelles Group (see Nature, p. 162), in a letter to the Paris Geographical Society. He has studied the fauna with some care, and remarks on the singular poverty of animal life compared with the great luxuriance of vegetation. In Port Victoria, the chief settlement in Mahé, the only form of butcher-meat obtainable is the flesh of the great turtle (*Chelone midas*) whose shell is valueless, the tortoise-shell fisheries of the island depending on the *Chelone imbricata*. M. Alluaud hopes to bring back with him living specimens of the elephantine turtles of the Aldabra Islands, specimens of which have been transported to the Seychelles.

The expectation of an Antarctic expedition, on which valuable scientific observations might have been made, has proved illusory. Captain Gray, of Peterhead, had organized a whaling voyage to the far south, and appealed to the public for funds to carry it out with some prospect of commercial success, but the response was so unsatisfactory that the enterprise has been abandoned. From a scientific point of view, the advantages of Antarctic exploration are so great, and the probability of valuable practical results so apparent, that the apathy alike of the British and Australian Governments as well as of the general geographical public is incomprehensible. The fact that no steamer has ever been despatched to the south of the Antarctic Circle with the object of attaining high latitudes says much for the prudence and little for the energy of present-day explorers.

A Chair of Colonial Geography is about to be established at the Sorbonne for the special study of the French colonies.

The discovery of America by Columbus is to be celebrated in Hamburg on October 11 and 12 by gatherings of delegates from the German Universities and Geographical Societies, by whom papers bearing on German enterprise in the sixteenth century will be read. An exhibition of articles illustrating the early connection of Hamburg and America will also be held.

The Manchester Geographical Society has just published its *Journal* for July–September 1891, containing several interesting papers on India and a variety of short notices. It is unfortunate that the small local encouragement given to this Society makes the earlier publication of its memoirs impossible. Surely Manchester could afford and should endeavour to maintain a Geographical Society as prosperous financially as it is enterprising and persevering. The contrast between the many provincial Geographical Societies in Germany and France with the three already established in England corresponds to the relative interest in geography as an aid to commerce on the Continent and in Great Britain.

METALLIC CARBONYLS.[1]

JUSTUS LIEBIG, perhaps the most prophetic mind among modern men of science, wrote in the year 1834 in the *Annalen der Pharmacie*. "I have previously announced that carbonic oxide may be considered as a radical, of which carbonic acid and oxalic acid are the oxides, and phosgene gas is the chloride. The further pursuit of this idea has led me to the most singular and the most remarkable results."

Liebig has not told us what these results were, and it has taken many years before the progress of chemical research has revealed to us what may at that early date have been before Liebig's vision. I will to-night bring before you some important discoveries made only within the last few years by following up Liebig's idea.

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[1] Friday Evening Discourse delivered at the Royal Institution by Ludwig Mond, F.R.S., on June 3.

Carbonic oxide, composed of one atom of carbon and one atom of oxygen, is a colourless gas, without taste or smell, which I have here in this jar. It burns with a blue flame. When it acts as a radical combining with other bodies, we term it carbonyl, and its compounds with other elements or radicals are termed carbonyls.

Liebig defined a radical as a compound having the characteristics of a simple body, which would combine with, replace, and be replaced by simple bodies. In more modern times a radical has been defined as an unsatiated body. I am of course speaking of chemical radicals. If we look at it from the modern point of view, carbonyl should be the very model of a radical, because only half of the four valencies of the carbon atom are satiated, the other two remaining free. Carbonic oxide should even be a most violent radical, because, amongst all organic radicals, it is the only one we know to exist in the atomic or free state. All the other organic radicals, even such typical ones as cyanogen and acetylene, are known to us as molecules composed of two atoms of the radical, so that the cyanogen gas and acetylene gas we know should more properly be called di-cyanogen and di-acetylene; they consist of two atoms of the radical cyanogen or of the radical acetylene, the free valencies or combining powers of which satiate or neutralize each other. On the other hand, carbonic oxide gas, as I stated before, makes the sole exception. Its molecule contains only one atom of carbonyl moving about with its free valencies unfettered by a second atom. For all that, carbonic oxide is by no means a violent body, but the very reverse, and instead of being ready to attack with its two free valencies anything coming in its way, until very recently we only knew it to interact and to combine with substances possessing themselves extreme attacking powers, such as chlorine and potassium. Although Liebig had so long ago proclaimed it as a radical, the chemical world was startled when, two years ago, I announced in a paper I communicated to the Chemical Society in conjunction with Drs. Langer and Quincke, that carbonic oxide combines at ordinary temperature with so inactive an element as nickel, and forms a well-defined compound of very peculiar properties.

The fact that carbonic oxide does not possess the chemical activity one would suppose in a radical composed of single atoms may, I believe, be explained by assuming that the two valencies of carbon which are not combined with oxygen do satiate or neutralize each other. Everybody admits that the valencies of two different carbon atoms, which are all considered of equal value, can neutralize each other. I see, therefore, no reason to question the possibility of two valencies of the same carbon atom neutralizing each other. On this assumption carbonic oxide may be looked upon as a self-satisfied body—one which keeps in check its free affinities within itself.

You have here the typical carbon radicals containing one atom of that element, acetylene, methylene, methyl, cyanogen, and carbonyl. In the second column you have these substances as they are known to us in the free state. You see the carbonyl is the only one which exists in the free state as a single atom, while all the others only exist as molecules, composed of two atoms the free valencies of which neutralize each other. The carbonyl I have represented in the last formula, with the two valencies not combined with oxygen neutralizing each other, so that in this way it also becomes a satiated body. I will try to make this still plainer to you by means of the models I have before me.

The paper published by Liebig in 1834, from which I have already quoted, was entitled "On the Action of Carbonic Oxide on Potassium." In it Liebig fully described the preparation and properties of the first metallic carbonyl known—a compound of potassium and carbonic oxide. Liebig obtained this compound by the direct action of carbonic oxide upon potassium at a temperature of 80° C., and proved it to be identical with a substance which had been previously obtained as a very disagreeable by-product of the manufacture of potassium from potash and carbon by Brunner's method. It forms a grey powder which is not volatile, and which on treatment with water yields a red solution, gradually turning yellow in contact with air, and from which on evaporation a yellow salt is obtained, called potassium croconate, on account of its colour. Liebig showed this salt to consist of two atoms of potassium, five of carbon, and five of oxygen, and not to contain any hydrogen, as had previously been supposed.

Since the publication of Liebig's paper, potassium carbonyl has been studied by numerous investigators, amongst whom Sir Benjamin Brodie deserves particular mention; but it has been reserved to Nietzki and Benkiser to determine finally in the year 1885, by a series of brilliant investigations, its exact constitution, and its place in the edifice of chemistry. They have proved that it has the formula $K_6C_6O_6$; that the six carbons in this compound are linked together in the form of a benzole ring; that, in fact, the compound is hexhydroxylbenzole, in which all the hydrogen is replaced by potassium. By simple treatment with an acid it can be converted into the hexhydroxylbenzole, and from this substance it is possible to produce, by a series of reactions well known to organic chemists, the whole wide range of the benzole compounds. The body which Liebig obtained by the direct action of carbonic oxide on potassium has thus enabled us to prepare synthetically in a very simple way from purely inorganic substances—to wit, from potash and carbon, or if we like even from potash and iron—the whole series of those most important and interesting compounds called aromatic compounds, including all the coal-tar colours, which have furnished us with an undreamt-of variety of innumerable hues and shades of colour, as well as many new substances of great value to suffering humanity as medicines. Surely a startling result, which alone would have fully justified Liebig's prediction of 1834!

Speaking of coal-tar colours, everybody will be reminded of the great loss the scientific world has recently sustained by the death of August Wilhelm Hofmann, their first discoverer, Liebig's greatest pupil. Hofmann will ever be remembered in this Institution, where he so often delighted the audience by his lucid lectures, and in whose welfare he took the greatest interest, of which he gave us a fresh proof only last year, in the charming letter he wrote on the occasion of his election as an honorary member.

Looking back upon the wonderful outcome of Liebig's idea I have referred to, it seems surprising indeed that others should not have followed up his work by attempting to obtain other metallic carbonyls.

A very few experiments were made with other alkaline metals: sodium, otherwise resembling potassium so closely, has been shown not to combine with carbonic oxide; lithium and cæsium are stated to behave similarly to potassium. But metals of other groups received little or no attention. The very important *rôle* which carbonic oxide plays in the manufacture of iron did lead a number of metallurgists (among whom Sir Lowthian Bell and Dr. Alder Wright are the most prominent) to study its action upon metallic iron and other heavy metals, including nickel and cobalt at high temperatures. They proved that these metals have the property to split up carbonic oxide into carbon and carbonic acid at a low red heat, a result of great importance, which threw a new light upon the chemistry of the blast furnace. None of these investigators, however, turned their attention to obtaining compounds of these metals with carbonic oxide, and, owing to the high temperature and the other conditions under which they worked, the existence of such compounds could not come under their observation. In order to obtain these compounds, very special conditions must be observed, which are fully described in the papers I have published during the last two years in conjunction with Dr. Langer and Dr. Quincke.

The metals must be prepared with great care, so as to obtain them in an extremely fine state of division, and must be treated with carbonic oxide at a *low temperature*. The best results are obtained when the oxalate of the metal is heated in a current of hydrogen at the lowest temperature at which its reduction to the metallic state is possible. I have in the tube before me metallic nickel prepared in this way, and over which a slow current of carbonic oxide is now passing; the carbonic oxide before entering the tube burns, as you see, with a blue non-luminous flame. After passing over the nickel it burns with a highly luminous flame, which is due to the separation of metallic nickel from the nickel carbonyl formed in the tube, which is heated to incandescence in the flame. (In passing the gas issuing from our tube through a glass tube heated to about 200°, we obtain a metallic mirror of pure nickel, because at this temperature the nickel carbonyl is again completely resolved into its components, nickel and carbonic oxide. If we pass the gas through a freezing mixture, you will observe that a colourless liquid is condensed, of which I have a larger quantity standing in this tube. This liquid formed is pure nickel carbonyl, and has the formula $Ni(CO)_4$.

If cooled to $-25°$ C., it solidifies, forming needle-shaped crystals. The vapour of nickel carbonyl possesses a characteristic odour and is poisonous, but not more so than carbonic oxide gas. Prof. McKendrick has studied the physiological action of this liquid, and has found that, when injected subcutaneously in extremely small doses in rabbits, it produces an extraordinary reduction in temperature, in some cases as much as 12°.

The liquid can be completely distilled without decomposition, but from its solution in liquids of a higher boiling-point it cannot be obtained by rectification. On heating such a solution the compound is decomposed, nickel being separated in the liquid, while carbonic oxide gas escapes. I will try to demonstrate this by an experiment.

We have here a solution of the substance in heavy petroleum oil, which you will, in a few minutes, see turns completely black on heating by the separation of nickel, while a gas escapes which is carbonic oxide.

In a similar way, when the nickel carbonyl is attacked by oxidizing agents, such as nitric acid, chlorine, or bromine, it is readily broken up, nickel salts being formed, and carbonic oxide being liberated. Sulphur acts in a similar way. Metals, even potassium, alkalies, and acids, which have no oxidizing power, will not act upon the liquid at all, nor do the salts of other metals react upon it. The substance behaves therefore, chemically, in an entirely different manner from potassium carbonyl, and does not lead, as the other does, by easy methods to complicated organic compounds. It does not show any one of the reactions which are so characteristic for organic bodies containing carbonyl, such as the ketones and quinones; and we have not been able, in spite of very numerous experiments, either to substitute the carbonic oxide in this compound by other bivalent groups, or to introduce the carbonic oxide by means of this compound into organic substances.

By exposing the liquid to atmospheric air, a precipitate of carbonate of nickel is slowly formed of varying composition, which is yellowish-white if perfectly dry air is used, and varies from a light green to a brownish colour if more or less moisture is present. We have found all these precipitates to dissolve easily and completely in dilute acid, with evolution of carbonic acid, leaving ordinary nickel salts behind, and can therefore not agree with the view propounded by Prof. Berthelot, in a communication to the French Academy of Sciences, that these precipitates contain a compound of nickel with carbon and oxygen, comparable to the so-called oxides of organo-metallic compounds. In the same paper Prof. Berthelot has described a beautiful reaction of nickel carbonyl with nitric oxide, which we will now show you. You will notice the intense blue coloration which the liquid solution of nickel carbonyl in alcohol assumes by passing the nitric oxide through it. Prof. Berthelot has reserved to himself the study of this interesting body, but has so far not published anything further about it.

The chemical properties of the compound I have just described to you are without parallel; we do not know a single substance of similar properties. It became, therefore, of special interest to study the physical properties of the compound.

Prof. Quincke, of Heidelberg, has kindly determined its magnetic properties, and found that it possesses in a high degree the property discovered by Faraday, and called by him diamagnetism, which is the more remarkable, as all the other nickel compounds are paramagnetic. He also found that it is an almost perfect non-conductor of electricity, in this respect differing from all other nickel compounds.

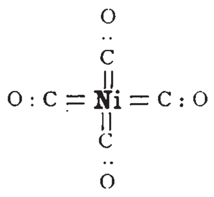
The absorption spectrum, and also the flame spectrum, of our compound are at present under investigation by those indefatigable spectroscopists, Profs. Dewar and Liveing, by whose kindness I am enabled to bring before you, in advance of a paper they are sending to the Royal Society, some of the interesting results they have obtained. We have here a photograph of the absorption spectrum, obtained by means of a hollow prism through quartz plates filled with nickel carbonyl, through which the spark spectrum of iron is passed, which is photographed on the same plate. You see that the whole of the ultra-violet rays of the iron spectrum have disappeared, being completely absorbed by the nickel carbonyl, which is thus quite opaque for all the rays beyond the wave-length 3820. The spectrum of the highly luminous flame of nickel carbonyl, which I have shown you before, is quite continuous; but if the nickel carbonyl is diluted with hydrogen, and the mixture burnt by means of oxygen, the gases burn with a bright yellowish-green flame without visible smoke; and the spectrum of this flame shows in its visible part, on a background of a continuous spectrum, a large number of bands, brightest in the green, but extending on the red side beyond the red line of lithium, and on the violet side well into the blue. These bands cannot be seen on the photograph which I will now show you, the visible part of the spectrum appearing continuous; but beyond the visible part the photograph shows a large number—over fifty—of well-defined lines in the ultra-violet. I will show you these lines in another photograph taken with greater dispersion, and on which has also been photographed the spark spectrum of nickel. You will see that all these lines correspond absolutely to lines appertaining to the spark spectrum; in fact, the greater part of the lines in the spark spectrum are also shown in this flame spectrum. We have here another and very striking example of the fact discovered on the same day by Profs. Dewar and Liveing, and by Dr. Huggins, that the spectrum of luminous flames is not always continuous throughout its whole range, a fact which was at one time much debated and discussed.

One of the most remarkable discoveries made within the precincts of this Institution by that illustrious man whose centenary we celebrated last year was that of the connection between magnetism and light, which manifests itself when a beam of polarized light is sent through a substance while it is subjected to a strong magnetic field, under whose influence the beam of light is rotated through a certain angle. Dr. W. H. Perkin has prosecuted this discovery of Faraday's by a long series of most elaborate researches, and has established the fact that this power of magnetic rotation of various bodies has a definite relation to their chemical constitution, and enables us to gain a better insight into the structure of chemical compounds. Dr. Perkin has been good enough to investigate the power of magnetic rotation of the nickel carbonyl, and has found it quite as unusual as its chemical properties, and to be, with the sole exception of phosphorus, greater than that of any other substance he has yet examined.

The power of different bodies of refracting and dispersing a ray of light has been shown by the beautiful and elaborate researches undertaken many years ago by Dr. Gladstone—who has given an account of them in this theatre in 1875, and who has since continued them with indefatigable zeal—to throw a considerable light upon the constitution of chemical compounds.

I have investigated the refractive and dispersive powers of nickel carbonyl in Rome, in conjunction with Prof. Nasini. We found that the atomic refraction of nickel in the substance is nearly two and a half times as large as it is in any other nickel compound—a difference very much greater than had ever before been observed in the atomic refraction of any element. To give you some idea how these figures are obtained, Mr. Lennox will now throw on to the screen a beam of light through two superposed prisms, one filled with nickel carbonyl and the other with alcohol. You will notice that the lines of the spectrum on the top are turned much further to the left, showing the nickel carbonyl to possess a much greater power of refraction than alcohol, and you will also notice that it is much wider than the bottom spectrum, which shows the greater dispersive power of the nickel carbonyl.

It is now generally supposed that, if one element shows different atomic refractive powers in different compounds, it enters with a larger number of valencies into the compound which shows a higher refractive power. In accordance with this view, the very much greater refractive power of the nickel in the carbonyl would find an explanation in assuming that this element, which in all its other known combinations is distinctly bivalent, exercises in the carbonyl the limit of its valency, viz. 8, assigned to it by Mendeleeff, who placed it in the eighth group in his Table of Elements. This would mean that the one atom of nickel contained in the nickel carbonyl is combined directly with each of the four bivalent atoms of carbonyl, each of which would saturate two of the eight valencies of nickel, as is shown by this formula—



$$\begin{array}{c} \mathrm{O} \\ \cdot\cdot \\ \mathrm{C} \\ \| \\ \mathrm{O : C} = \mathbf{Ni} = \mathrm{C : O} \\ \| \\ \mathrm{C} \\ \cdot\cdot \\ \mathrm{O} \end{array}$$

This view seems plausible, and in accordance with the chemical properties of the substance, and I should have no hesitation in accepting it if we had not, in the further pursuit of our work on metallic carbonyls, met with another substance—a liquid compound of iron with carbonic oxide—which in its properties bears so much resemblance to the nickel compound that one cannot assign to it a different constitution, whilst its composition makes the adoption of a similar structural formula next to impossible. It contains, for one equivalent of iron, five equivalents of carbonyl. To assign to it a similar constitution, one would, therefore, have to assume that iron did exercise ten valencies, or two more than any other known element, a view which very few chemists would be prepared to countenance. The atomic refraction of iron in this compound, which Dr. Gladstone has had the kindness to determine, is as unusual as that of the nickel in the nickel compound, and bears about the same ratio to the atomic refraction of iron in other compounds. We have, therefore, to find another explanation for the extraordinarily high atomic refraction of these metals in their compounds with carbon monoxide, which may possibly modify our present view on this subject. As to the structure of these compounds themselves, we are almost bound to assume that they contain the carbonyl atoms in the form of a chain.

The ferro-carbonyl is prepared in a similar manner to the nickel compound. The iron used is obtained by heating iron oxalate at the very lowest temperature possible. This carbonyl forms, however, with such very great difficulty, that we overlooked its existence for a long time, and great precautions have to be taken to obtain even a small quantity of it. It forms an amber-coloured liquid, of which I have a small quantity before me. It solidifies below − 21° C. to a mass of needle-shaped crystals. On heating the vapour to 180° C., it is completely decomposed into iron and carbonic oxide. The iron mirrors before me have been obtained in this way. Its chemical composition is $Fe(CO)_5$.

It is interesting that, within a short time after we had made known the existence of this body, Sir Henry Roscoe found it in carbonic oxide gas which had stood compressed in an iron cylinder for a considerable time, and expressed the opinion that the red deposit which sometimes forms in ordinary steatite gas-burners is due to the presence of this substance in ordinary illuminating gas. Its presence in compressed gas used for lime-lights has been noticed by Dr. Thorne, whose attention was called to the fact that this gas sometimes will not give a proper light because the incandescent lime becomes covered with oxide of iron.

M. Garnier, in a paper communicated to the French Academy of Sciences, supposes even that this gas is sometimes formed in large quantities in blast-furnaces when they are working too cold, and refers to some instances in which he found large deposits of oxide of iron in the tubes leading away the gas from these furnaces. I find it difficult to believe that the temperature of a blast-furnace could ever be sufficiently reduced as to give rise to the formation of this compound. On the other hand, it is highly probable that the formation of this compound of iron and carbonic oxide may play an important *rôle* in that mysterious process by which we are still making, and have been making for ages, the finest qualities of steel, called the cementation process.

The chemical behaviour of the substance towards acids and oxidizing agents is exactly the same as that of the nickel compound, but to alkalies it behaves differently. The liquid dissolves without evolution of gas. After a while a greenish precipitate is formed, which contains chiefly hydrated-ferrous oxide, and the solution becomes brown. On exposure to the air, it takes up oxygen; the colour changes to a dark red, whilst hydrated ferric oxide separates out.

We have so far not been able to obtain from this solution any compound fit for analysis, and are still engaged upon unravelling the nature of the reaction that takes place, and of the compounds that are formed.

Although the solution resembles in appearance to some extent the solutions obtained by treating potassium carbonyl with water, it does not give any of the characteristic reactions of the latter.

When speaking of potassium carbonyl, I mentioned that, by its treatment with water, croconate of potassium was obtained, which has the formula $K_2C_5O_5$. We have transformed this by double decomposition into ferrous croconate (FeC_5O_5), a salt forming dark crystals of metallic lustre resembling iodine, which is not volatile, and dissolves readily in water, the solution giving all the well-known reactions of iron and of croconic acid. You will note how entirely different the properties of this substance are from those of iron carbonyl, which I have described to you; yet, on reference to its composition, you will find that it contains exactly the same number of atoms of iron, carbon, and oxygen as the latter. This is a very interesting case of isomerism, considering that both compounds contain only iron, carbon, and oxygen.

The difference in the properties of these two bodies becomes explainable by comparing the structural formula of the two substances.

I would now call your attention to the great difference in the constitution of the potassium carbonyl and that of the nickel and ferro carbonyl. In the former the metal potassium is combined with the oxygen in the carbonyl; in the latter the metals nickel and iron are combined with the carbon of carbonyl. In the first case we have a benzole ring with its three single and three double bonds; in the second a closed chain with only single bonds. It is evident that the chemical properties of these substances must be widely different.

The ferro-penta-carbonyl remains perfectly unchanged in the dark, but if it is exposed to sunlight it is transformed into a solid body of remarkably fine appearance, of gold colour and lustre, as shown by the sample in this tube.

This solid body is not volatile, but on heating it in the absence of air, iron separates out and liquid ferro-carbonyl distils over. If, however, it is heated carefully in a current of carbonic oxide it is reconverted into the ferro-penta-carbonyl, and completely volatilized. We have so far found no solvent for this substance, so that we have no means as yet of obtaining it in a perfectly pure state. Several determinations of the iron in different samples of the substance have led to fairly concordant figures, which agree with the formula $Fe_2(CO)_7$, or di ferro-hepta-carbonyl.

The interesting properties of the substances described have naturally led us "to try," as Lord Kelvin once put it to me so prettily, "to give wings to other heavy metals." We have tried all the well-known and a very large number of the rarer metals; but with the exception of nickel and iron we have so far been entirely unsuccessful. Even cobalt, which is so very like nickel, has not yielded the smallest trace of a carbonyl. This led me to study the question whether, by means of the action of carbonic oxide, the separation on a large scale of nickel from cobalt could not be effected, which has so far been a most complicated metallurgical operation; and subsequently I was led to investigate whether it would not be possible to use carbonic oxide to extract nickel industrially direct from its ores.

It had been established that pure nickel prepared with very great precautions in a glass tube, could be partly volatilized by carbonic oxide, and that from the gas thus obtained the nickel could be separated again by heating. The questions to be studied were, therefore, whether it would be possible to reduce the ores, on an industrial scale, under such conditions as to obtain the nickel in a sufficiently finely divided and active a state that the carbonic oxide would volatilize it; whether such action would be sufficiently rapid to allow of its industrial application; whether it would be sufficiently complete to remove all the nickel from the ore; and whether none of the other constituents of the ore would pass with the nickel and render it unfit for use; and further, whether the nickel could be completely separated out of the gas within practical limits; and whether the recovered carbonic oxide could be made use of over and over again.

For solving these problems within the limits of the resources of a laboratory, I have devised apparatus which consists of a cylinder divided into many compartments, through which the properly prepared ore is passed very slowly by means of stirrers attached to a shaft. On leaving the bottom of this cylinder, the ore passes through a transporting screw, and from this to an elevator, which returns it to the top of the cylinder, so that it passes many times through the cylinder, until all the nickel is volatilized. Into the bottom of this cylinder we pass carbonic oxide, which leaves it at the top charged with nickel carbonyl vapour, and passes through the conduits shown here into tubes set in a furnace and heated to 200°. Here the nickel separates out from the nickel carbonyl. The carbonic oxide is regenerated and taken back to the cylinder by means of a fan, so that the same gas is made to carry fresh quantities of nickel out of the ore in the cylinder, and to deposit it in these tubes an infinite number of times.

Upon these principles Dr. Langer has constructed a complete plant on a Liliputian scale, which has been at work in my laboratory for a considerable time, and a photograph of which we will now throw on to the screen. You see here the volatilizing cylinder divided into numerous compartments, through which the ore is passing, and subjected to the action of carbonic oxide. At the bottom the ore is delivered into the transporting screw, passing through a furnace, and from this screw into an elevator, which returns the ore to the top of the cylinder, so that the ore constantly passes at a slow rate through the cylinder again and again, until the nickel it contains has been taken out. The carbonic oxide gas, prepared in any convenient manner, enters the bottom of the cylinder and comes out again at the top. It then passes through a filter to retain any dust it may carry away, and thence into a series of iron tubes built into a furnace, where they are heated to about 200° C. In these tubes the nickel carbonyl carried off by the carbonic oxide is completely decomposed, and the nickel deposited against the sides of the tubes is from time to time withdrawn, and is thus obtained in the pieces of tubing and the plates which you see on the table.

The carbonic oxide regenerated in these tubes is passed through another filter, thence through a lime purifier, to absorb any carbonic acid which may have been formed through the action of the finely-divided nickel upon the carbonic oxide, and is then returned through a small fan into the bottom of the cylinder. The whole of this plant is automatically kept in motion by means of an electric motor, and the gearing which you see here.

By means of this apparatus we have succeeded in extracting the nickel from a great variety of ores, in a time varying, according to the nature of the ore, between a few hours and several days.

Before the end of this year this process is going to be established in Birmingham on a scale that will enable me to place its industrial capacity beyond a doubt, so that I feel justified in the expectation that in a few months nickel carbonyl, a substance quite unknown two years ago, and to-day still a great rarity, which has not yet passed out of the chemical laboratory, will be produced in very large quantities, and will play an important *rôle* in metallurgy.

The process possesses, besides its great simplicity, the additional advantage that it is possible to immediately obtain the nickel in any definite form. If we deposit it in tubes we obtain nickel tubes; if we deposit it in a globe we obtain a globe of nickel; if we deposit it in any heated mould we obtain copies of these moulds in pure, firmly coherent, metallic nickel. A deposit of nickel reproduces the most minute details of the surface of the moulds to fully the same extent as galvanic reproductions. All the very numerous objects now produced by galvanic deposition, of which Mr. Swan exhibited here such a large and beautiful variety a fortnight ago, can thus be produced by this process with the same perfection in pure metallic nickel. It is equally easy to nickel-plate any surface which will withstand the temperature of 180° C. by heating it to that temperature and exposing it to the vapour, or even to a solution of nickel carbonyl, a process which may in many cases have advantages over electroplating. I have on the table before me specimens of nickel ores we have thus treated, of nickel tubes and plates we have obtained from these ores, and a few specimens of articles of pure nickel and articles plated with nickel which have been prepared in my laboratory. These will give you some idea of the prospects which the process I have described opens out to the metallurgist, upon whom, from day to day, greater demands are made to supply pure nickel in quantities. The most valuable properties of the alloy of nickel and iron called nickel-steel, which promises to supply us with impenetrable ironclads, have made an abundant and cheap supply of this metal a question of national importance. The inspection of the few specimens of articles of pure nickel and of nickel-plated articles will, I hope, suffice to show you the great facilities the process offers for producing very fine copies, and for making articles of such forms as cannot be produced by hydraulic pressure, the only method hitherto available for manufacturing articles of pure nickel.

The first practical use of the process has been made by Prof. Ramsay, who, for the purposes of a chemical investigation, made this beautiful little apparatus of pure nickel all in one piece, which he has kindly lent for exhibition to-night.

I began my lecture by bringing under your notice an idea of Liebig's which he published fifty-eight years ago. I have shown you how he himself elaborated this idea, and how it developed, until within recent years it has led to results of the highest scientific importance and probably of great practical utility.

Had Liebig all these results before his "mind's eye" when he penned those prophetic words I have quoted? This is a question impossible to answer. Who will attempt to measure the range of vision of our great men, who from their lofty pinnacle see with eagle eye far into the Land of Science, and reveal to us wonderful sights which we can only realize after toiling slowly along the road they have indicated? Whether Liebig saw all these results or not, it is due to him and to men like him that science continues its marvellous advance, dispersing the darkness around us, and ever adding to the scope and exactness of our knowledge, that mighty power for promoting the progress and enhancing the happiness of humanity.

NORTH-WESTERN DISTRICT OF BRITISH GUIANA.

At the meeting of the Royal Geographical Society on Monday evening, Mr. Everard im Thurn described the general characteristics of the new district in the north-west of British Guiana in the settlement and administration of which he has been employed for the last nine years. The colony of British Guiana he described as formed of a low swampy coast strip, often below the level of the sea, densely covered with mangroves, and intersected by rivers bound together by interlacing channels. Farther inland the mangroves pass into forests of tropical trees, which, as the land rises more steeply, are reduced to strips along the rivers, and finally merge into dry grassy uplands known as savannahs. The north-western district of the colony is officially defined as the territory bounded on the north by the Atlantic Ocean and the mouth of the River Orinoco; on the south by the ridge of land between the sources of the Amakuru, Barima, and Waini Rivers, and their tributaries, and the sources of the tributaries of the Cuyuni River; on the east by a line extending from the Atlantic Ocean in a southerly direction to the said ridge of land; on the south and on the west, by the Amakuru River and the line known as Schomburgh's line.

Mr. im Thurn's first task was to explore his territory, and this he did mainly by boat along the rivers and their connecting channels, traversing country never before visited by white men. The nature of this mode of travelling was very vividly described. On ascending the Moruka, the country on each side of the river was seen to become gradually more and more open—the river at last often winding through open savannahs, and broadening out here and there into pools so thickly set with water-lilies that the boat was forced through with difficulty. The waterway after some time leaves the river and passes along a narrow itabbo, or artificial water-path, which connects the Moruka with the Waini River. This connecting passage is about thirty miles long, and about ten miles is semi-artificial itabbo, made by the constant passage of the canoes of the Redmen through the swampy savannah, and very difficult to get through. Generally, it was hardly wider than the boat, and had many abrupt windings; the trees hung down so low over the water, that it was hard work either to force the boat under the low-lying branches, or to cut these away, and so make a passage. On either side of the channel the ground is so swampy as rarely to allow foothold of even a few inches in extent. The light hardly penetrates through the dense roof of leaves; and in the gloom under the roof only a few aroids, ferns, lilies, and orchids, and great masses of a palm previously undescribed could be described.

The itabbo passed, the boat turned suddenly into the Barabara River itself, at first narrow, but soon widening and winding on its course through dense and unbroken bush, chiefly composed of the graceful, swaying manicole palms (*Euterpe edulis*). Very abundant, perched high up and low down among this dense bush, were great quantities of an orchid with stems eight and nine feet long, loaded with its countless butterfly-like yellow flowers (*Oncidium altissimum*). After a few miles the Barabara River led into the Biara, a river of much the same character, which, though naturally larger than the Barabara, was still so small as hardly to deserve more than the local name of creek. And, again, in a few miles the Biara carried the boat into the Baramanni River, which is about 100 or 150 yards wide, and very deep. This is, in fact, not a river at all, but a very elongated lake or lagoon, of perhaps twenty miles in length, the lower end